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How does VO_2 evolve during the 800m?

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ABSTRACT

The purpose of this experiment was to examine the evolution of the ventilatory parameters during 800 meters when 800 meters are realized according to the competition model: fast departure and drop in the speed in the final 100 meters. To date, concerning supramaximal exercises only studies realized in constant power had been proposed. Our results indicate that, regarding VO_2, the 800m can be described by 3 different phases: 1) during the first 315 metres, VO_2 increases gradually to reach VO_2 max, 2) during the 215m which follow or until the 530m, VO_2 max is maintained, and finally 3) during the last 270 m, VO_2 decreases gradually to reach 80 % of VO_2max at the end of running. It thus seems that the fact of leaving faster than the average speed of running allows to reach VO_2max and it more quickly. It also seems that at the same time as the fall of the speed, one can observe VO_2's fall at the end of the running.

AUTHOR

C. Hanon, C. Thomas, JM Le Chevalier, B Gajer and H Vandewalle are members or students of INSEP, the french olympic campus. C. Hanon, PhD, was a 800 meters runner. INSEP has dedicated its life to Elite sport performance since its creation in 1945. It offers optimal education opportunities to elite athletes, who can study (high school and university) and prepare their professional career while training for international events. The 850 athletes who live there are recruited by their respective national sports federations and benefit from all available equipment and infrastructure, including a Sport Sciences Department whose priority is to favour the scientific environment of sport and high level performance.

I. Introduction

In order to answer this question, it has to date been necessary to either examine the rare studies carried out on treadmill to high speeds, or to consult the results of experiments carried out using the cycle ergometer. In both cases, a considerable disparity remains concerning the 800m: either the exercise is realized in constant power, or it does not refer to the specific activity of running.

The technological progress and the miniaturisation of devices intended to record the consumption of oxygen enable these two problems to be solved, to test the evolution of VO_2 in running, and according to the characteristics of 800m.

II. The 800m

Reminder: it is possible to notice that all the 800m run with the intention of realising a chronometric performance, are realized according to a common model (for details, to refer to the book " the 800m, the descriptive analysis and the training " from Gajer et al. 2000). This model advances the fact that the running is not based on the regularity of speed, but on the contrary on a fast departure, followed by a plateau of 500m and by a drop in the speed over the final 100m. It is noted that this drop is even marked for elite runners and that this profile of evolution of the speed is carried over to other disciplines (standing start kilometre in cycling, 500 meters kayak, notably). Our study thus based itself on this chronometric model to calibrate the running of the participating athletes.

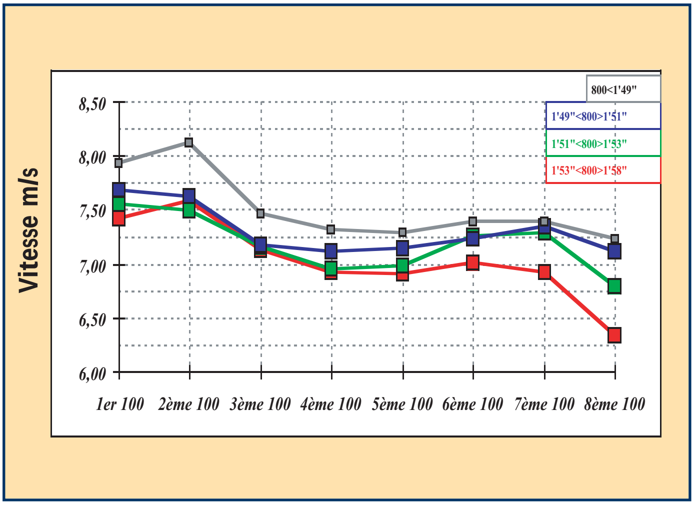

Figure 1: Evolution of the speed during the 800m according to the levels of performance. According to Gajer et al. 2000

III. The questions

The VO_2max value is determined during the progressive test carried out on the track (test of TUB2). This value will be compared with the VO_2 maximal value collected during the 800m, which we shall call $VO_2$800.

Our experiment is aimed at describing the evolution of VO_2 during the test. It is possible to distinguish 3 questions:

1-$VO_2$800 value corresponds it to the VO_2max value? In other words, does one reach VO_2max during the 800m?

2-if yes, at what stage?

3-if yes, does one maintain VO_2max up to the end of the 800m?

III.1 - Does one reach VO_2 max during the 800m?

For Astrand and Rodahl (1994), " an exercise for one minute or even less can involve in a maximal way the system of transport of the oxygen ". Gastin and Lawson (1994), Granier (1995) showed this during all-out tests realised on bicycle ergometers as well as Billat et al. 2000 for running exercises carried out at 120 % of VO_2max until exhaustion.

On the other hand, for Heugas et al. 1995, VO_2max is not reached on treadmill running for an exercise carried out at 130 % of VO_2max during approximately 1 min 30. With regard to the 800m, Spencer et al. (1996) and Spencer and Gastin (2001) simulated 800 meter running on treadmill, and showed that the athletes did not reach VO_2max in these conditions. It is noted that these studies carried out at constant power, were carried out at only 112 and 113 % of MAS (Maximal Aerobic Speed) while according to Lacour (1990), for an 800m at national level is reached at 120% of MAS.

III. 2 - At what stage does one reach $VO_2$800 or VO_2max?

According to Margaria and al. 1965, VO_2max is reached all the more quickly with intense exercise. The studies conducted in this area have presented results that differ, depending on whether the exercise is realised in constant power or not.

So on a cycle ergomerter (Withers et al. 1991), or in a kayak (Zamparo et al. 1999), the power of the exercise is more important at the beginning of the effort than the average the power of the exercise. This could explain a faster adaptation of the consumption of oxygen. On the contrary, in the study of Nummela and Rusko (1995), the power of the exercise on treadmill running is constant. The athletes in this study reached a VO_2 equal to 79 % of VO_2max at the end of the test.

So, it can be interesting to look at 800m running in its reality, where the departure is faster than the average speed of running to determine at which moment VO_2 peak is reached.

III.3 - Does one maintain VO_2 800 or VO_2 max during the 800m?

This question cannot be supported by the knowledge of the previous studies. It is indeed more the observation of the progress of the running that leads(infers) us to put forward this hypothesis. The athletes slow down at the end of 800m but the speed at the end of running remains superior to MAS. Some researchers before us among whom Pérey & Candeau (1999) were able to note VO_2's decline at the end of exhausting tests realised to 95 % of VO_2 max.

Given that the 800m is unquestionably an exhausting event, it is possible to ask the question: is $VO_2$800 maintained up to the end of the race?

IV - Experimental design

The protocol is established by two different tests: a test to determine VO_2max on the track and a test to determine $VO_2$800.

IV.1 - The test to determine VO_2max on track

This test is called Test of the University of Bordeaux II (TUB II) according to Cazorla and Léger (1993). The athletes are equipped with a heart-rate monitor and with a K4 (portable gas analyser). The test consists of running on a track, with markers every 25m, for a succession of stages each of 3 minutes duration, beginning at 14 km h-1 and increasing by 2 kmh-1 up to 18 km h-1, then by 1 km h-1 to the superior speeds. These stages are separated by one minute of recovery to allow a sample of blood to be taken. At each stage, the athletes should follow the speed imposed by a broadcasting device of sound signals (which replaces the usual cassette) The test is stopped when the athletes are not capable any more of following the rhythm imposed by the signals and are unable to make the mark by the signal

IV.2 - The 800m

The athlete is asked to perform a regular warm-up (jogging, stretches, mobility exercises, straight lines), and each athlete performs exactly the same warm-up. This is followed by a break of 4 minutes. The material (heart-rate monitor, K4) is gradually put on during the warm-up. For each runner, the speed is predetermined for the first 350 metres of running according to the model of running described by Gajer et al. (2000) and modulated with the athlete and the trainer according to the form and the specificity of the runner. Whistle blowing each 50m on the basis of established times allow to the athlete to adjust accordingly. An experimenter on bicycle accompanies and encourages the athlete.

A blood sample is taken at the end of the warm-up, at the end of the test and 3, 5, 7, and 10 minutes after the 800m. All the tests of 800m are filmed so as to determine a posteriori the exact speed.

IV.3 - Modalities of treatment of the results

Calculation of MAS on the track:

During the progressive test of TUB2, the speed maintained during the last stage fully completed by the runner, can be considered as the raw MAS, the energy of the last begun, but uncompleted stage, being mainly supplied by the anaerobic metabolism.

MAS's calculation from the energy cost

According to Lacour (1990), the MAS is equal to the report of the difference between VO_2max and VO_2 at rest in the arbitrarily chosen rest equal to 5 ml.kg-1.min-1 and the energy cost (guiding coefficient of the right-hand side of regression among O2 and the speed). It is this MAS value which is used in the relative expression (MAS) by the speed during the 800m.

Expression of the results obtained during the 800m

Treatment of the various data

With the chronometric performances of the athletes during the 800m being appreciably different, we normalised the results to homogenise the approach. By means of the times of passage in every 25m, we redefined curves according to the distance, which enables the same number of points (33) to be obtained and a normalisation clarifies every parameter for all the athletes.

V. Results

V.1 - Physiological characteristics of the subjects during the test of determination of VO_2max

1. Analysis of the test TUB2

The values of the morphological and physiological parameters (VO_2max, HRmax, VEmax, MAS (as previously described), maximal lactatemia) measured during the progressive test TUB2 are indicated in Table 1.

The VO_2max determination criteria are respected during this test for all the subjects. The level of the physiological characteristics of this group is representative of a population of well-trained middle-distance runners.

A. Analysis of the supramaximal test

1. Speeds and performances realised during the 800m

2. Results of the various parameters measured during the 800m

In Figure 2, one observes that the kinetics of VO_2 are broken down into three parts: a phase of inertia preceding a stable state of V

1-st phase: VO_2 inertia

From the test, VO_2 is 15,9 ± 4,8 ml.min-1.kg-1. 45s ± 10,6 of exercise later (that is 316m ± 74,9 metres), VO_2 stabilises at a mean value of 68,1 ± 5,4 ml.min-1.kg-1. According to Figure 1, one observes that the speed is not regular during the 800m. So, 75m of running later, the speed reaches a peak of 27, 3 ± 1,2 km h-1, sharply superior to the average speed of the test (23,9 ± 0,7 km h-1 is 120,8 ± 3,8 % of VO_2maxTUB2). However, the analysis 100m by 100m, indicates that it is the 2-nd 100 m that is the fastest.

VO_2max TUB2 (mlO2.min-1.kg-1)	**VEmax** (l.min-1)	**FCmax** (batt.min-1)	**MAS** (km.h-1)	**maximal Lactatémie** (mmol.l-1)
66,3 ± 2,3	129,2 ± 11,5	187 ± 12,7	19,2 ± 0,5	10,6 ± 2,5

Table 1 - Mean and standard deviations of the parameters determined during the progressive test TUB2

Realized Performances	**Average speed during 800m**	
	kma.h-1	% of the calculated MAS
120,8 ± 3,4	23,9 ± 0,7	123,9 ± 5,8

Table 2 - Summary of speeds and realized performances

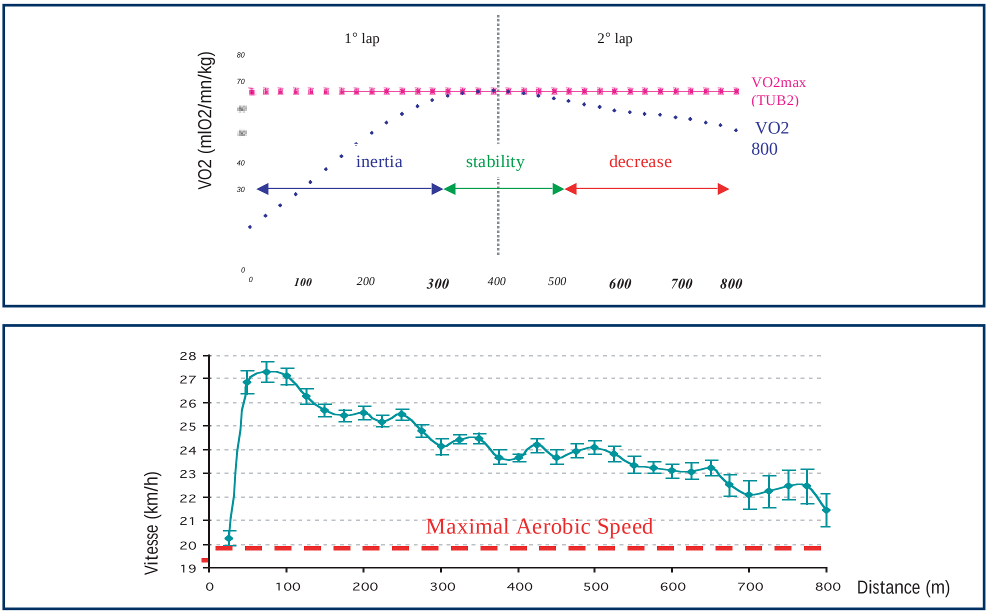

Fig.2 – Evolution of VO_2 and speed during 800 meters.

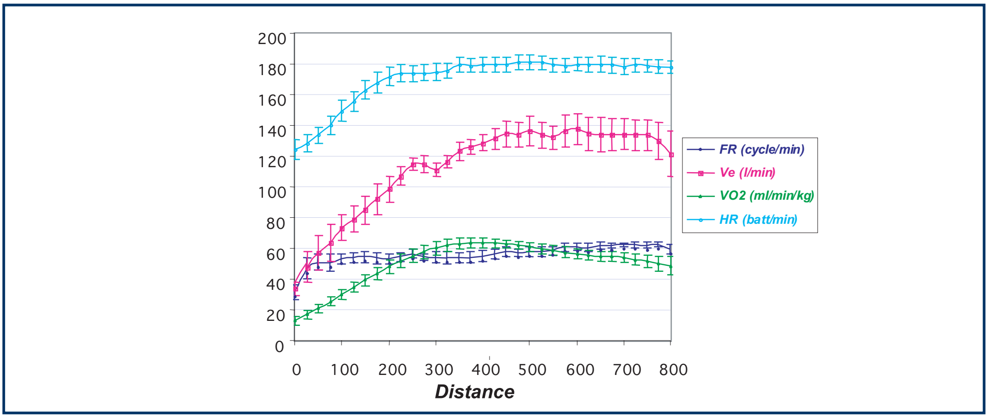

Fig. 3 Averages and standard deviations of 4 parameters (VO_2, VE, FC, FR) measured during the 800m

2-nd phase: VO_2 stable state

The value peak stable state average of VO_2 at the stable state is not significantly different ($p > 0{,}05$) from that measured during the TUB2 (66,3 ± 2,3 mlO2.min-1.kg-1). During this experiment, all the subjects reached their VO_2 maximal level. According to tables 3 and 4, this stable state of VO_2 is observed between 45 ± 10,6 and 78 ± 14,4 seconds, either between 316 ± 74,9 and 535 ± 104,9 metres, that corresponds to a duration of 33s ± 5,7, that is 219m ± 40,5 metres. The average speed at the level of this plateau amounts to 24 ± 0,5 km h-1. This value corresponds to 124,4 ± 5,8 % of MAS.

3-rd phase: decrease of O_2

According to tables 4 and 5, VO_2's decline begins at 78 ± 14,4 seconds, either 535 ± 104,9 metres, lasts 43,1s ± 16,8, that is 265 ± 104 metres. VO_2's value at the end of the 800m drops to 54,5 ± 7,1 mlO2.min-1.kg-1, which corresponds to 82,7 ± 9,3 % of VO_2maxTUB2. This represents a decrease of 20,6 ± 7 %. Furthermore, the mean value of VO_2max's stable state is significantly different ($p < 0,001$) to that averaged in the end of the 800m (54,5 + 7,1 ml.min-1.kg-1). This last value is statistically lower than that of the TUB2 ($p < 0,001$).

The speed decreases gradually to reach no more than 21,6 ± 1,8 km h-1 in the last ones 25m, what remains however superior to MAS (112,3 ± 9,6 % de MAS). Besides, there is no correlation ($r < 0,7$) between VO_2's decrease and fall of speed to all the subjects.

So regarding VO_2, the 800m can be described by 3 different phases:

- during the first 315 metres, VO_2 increases gradually to reach VO_2 max
- during the 215m which follow or until the 530m , VO_2 max is maintained
- during the 270 m of the end of running, VO_2 decreases gradually to reach 80 % of VO_2max at the end of running.

VI. Discussion

During this discussion, the reach of VO_2's peak, and its modalities will be firstly analysed. Then, we shall examine in the methodological, physiological and cellular plans the causes likely to provoke the decrease in VO_2 that arises at the end of this test.

VO_2max values: during this experiment, our results suggest that the subjects reach VO_2max with a peak value average of 69 ± 8,6 ml.min-1.kg-1. This value is not significantly different from that measured during the TUB2 (66,3 ± 2,3 ml.min-1.kg-1), and corresponds to their level.

VO_2 inertia: the VO_2max value after 45 ± 10,6 seconds confirms the hypothesis proposed by Lacour and al. (1990). On the other hand, they do not confirm those presented by Spencer and Gastin (2001) and those of Spencer et al. (1996), who suggest that only 90 % of VO_2max is reached during the 800m run on treadmill running. This difference between our results and those of these authors, can be explained by the shape of the running (faster departure), which should contribute to accelerate the kinetics of VO_2's adaptation and is reported in the works of Astrand and Saltin (1961) and Margaria et al. (1965) among others.

However, after the phase of inertia and VO_2's stable state, it emerges during the present study in the third phase of kinetic O2. This phase appears for all the athletes and is characterised by a significant decrease of O2 ($p < 0,05$), that we will now discuss.

VO_2: for all the subjects, VO_2 decreases by 20,6 ± 7 % very slowly and significantly ($p < 0,05$) from 78 ± 14,4 seconds (that is 535 +104,9 m), to a lower value (54,5 ± 7,1 mlO2.min-1.kg-1), that is lower than VO_2max ($p < 0,001$). The observation of this decline is contradictory to most of the results met in the literature.

Nevertheless, some authors among whom Numella and Rusko (1995) for the 400m, or Gastin and Lawson (1994), Perrey et al. (1999 and 2001) as well as figures presented in articles of Astrand and Saltin (1961), Gastin and Lawson (1994), Yamamoto and Kanehisa (1995), Zamparo et al. (1999), and Bishop et al. (2000) allow the same phenomenon to appear.

Besides the methodological causes which could be bound to the use of K4, the reasons mentioned to explain VO_2's fall can be of different nature:

The fall of the speed of running could be advanced. Nevertheless, in spite of this decline, the speed remains superior to the MAS of the subjects (on average 112,3 ± 9,6 % of MAS in the last ones 25mètres).

The physiological hypotheses allowing the fall in VO_2 at the end of exercise can be explained by hyperventilation (resulting from the lowering of the pH), the fatigue of the respiratory muscles and the decrease in Tidal volume (VT) noted in this study. All these factors result in the reduction in the possibility of gas exchange with the blood.

These observations were already described by Mahler and Loke (1981), but during athletic tests of long duration, and by Perrey and al. (2001) during an exercise realised at 95 % of VO_2max until exhaustion.

It is also possible to mention a possible decline of the cardiac output, the consequences of the blood acidosis on the fixation of the oxygen on red blood corpuscles and on functional capacities of the muscle.

VII. Conclusion

First of all, it is important to note that for this level of performance, 800 meters is run between 142 and 112% of MAS.

More generally, our results suggest that during supramaximal exercise of 800m, realised on the track and of variable intensity, the oxygen uptake of a trained individual reaches its maximal level after 45 ± 10,6 seconds (that is 316 ± 74,9 m), that it stabilises during 33 ± 5,7 s (that is 219 ± 40,5 m), and that it decreases slowly by 20,6 ± 7 % in all the subjects from 78 ±14,4 seconds (that is 535 ± 104,9 meters) while the exercise continues.

So, the reasons for the fast departures have, up to this point been explained only by strategic aspects: the fast departure of the 800m and perhaps the short distances can allow VO_2max to be reached during the 800m, and more particularly, to be reached more quickly. This would seem to help to explain the fact that 100 % of the records on 800m are realised according to this model of distribution of effort.

Obviously, it is a question of starting fast while being capable of remaining relaxed and thus possessing a reserve with regard to maximal speed (which probably implies that emphasis should be placed on the development of strength, speed and running technique).

Regarding VO_2max values during the 800m, it is necessary even for this to be put into perspective. This fact implies certainly that it is necessary to develop the aerobic part of training, but the results of the study also teach us that this VO_2max level is maintained only during 200m or so of the running...

The brevity of the 800m and the extreme demand imposed on athletes, means that this supramaximal exercise creates a state of imbalance within the body: notably, the decline of the blood pH and the excessive functioning of certain compartments, which lead the body to the exhaustion. The observation of the decline of O2 would be one of the resultants.

References

ASTRAND PO, Rodahl K *Précis de physiologie de l'exercice musculaire.* 3 rd edition, MASSON(1994)

BILLAT V, MORTAN RH, BLONDEL N, BERTHOUIN S, BOCQUET V, KORALSZTEIN JP, BARSTOW TJ. Oxygen kinetics and modelling of time to exhaustion whilst running at various velocities at maximal oxygen uptake. *Eur J Appl Physiol* 82: 178-187 (2000)

BISHOP D, BONETTI D, DAWSON B The influence of warm-up intensity on supramaxiaml kayal performance. *5 th annual congress of the european college of sport science Jyvaskyla Finland.* Short communication p162 (2000)

CAZORLA C, Léger L *Comment évaluer et développer vos capacités aérobies? Epreuve de course navette et épreuve vameval?* Edition Association Recherche et evaluation en activité physique et en sport (1993)

GAJER B, HANON C, MARAJO J, VOLLMER JC. *Le 800 mètres: analyse descriptive et entraînement.* Collection entraînement INSEP (2000)

GASTIN PB, LAWSON DL Influence of training status on maximal accumulated oxygen deficit during supramaximal all-out and constant intensity exercise. *Med Sci Sports Exerc* 27: 255-263 (1994)

GRANIER P, MERCIER B, MERCIER J, ANSELME F, Préfaut C Aerobic and anaerobic contribution to Wingate performance in sprint and middle-distance runners. *Eur J Appl Physiol* 70:58-65 (1995)

LACOUR JR, BOUVAT E, BARTHELEMY JC. Post competition blood lactate concentrations as indicators of anaerobic energy expenditure during 400-m and 800-m races. *Eur J Appl Physiol* 61:172-176 (1990)

NUMMELA A, RUSKO H Time course of anaerobic and aerobic energy expenditure during short-therm exhaustive running in athletes. *Int J Sports Med* 16:522-527 (1995)

MAHLER DA, KOKE J Lung function after marathon at warm and cold ambient temperatures. *Med Sci Sports* 8:14-47 (1981)

MARGARIA R, MANGILI F, CUTTICA F, CERRETELLI P The kinetics of the oxygen consumption at the onset of muscular exercise in man. *Ergonomics* 8: 49-54 (1965)

PEREY S, CANDEAU R, MILLET GY, BORRANI F, Rouillon JD Chute de la consommation d'oxygène à la fin d'un exercice exhaustif chez des coureurs à pied entraînés. Communication dans le cadre du colloque "*Biologie de l'exercice musculaire*" Clermont-Fr=errand 28-29 mai (1999)

PERREY S, CANDEAU R, MILLET GY, BORRANI F Rouillon JD Dercease in oxygen uptake at the end of a high-intensity submaximal running in humans. *Int J Sports Med* (2001)

SPENCER MR, GASTIN PB, PAYNE WR. Energy system contribution during 400 to 1500 meters running. *New studies in Athl* 11: 59-65 (1996)

SPENCER MR, GASTIN PB Energy contribution during 200- to 1500-m running in highly trained athetes. *Med Sci Sports Exerc* 33: 157-162 (2001)

WITHERS RT, SRHERMAN WM, CLARK DG, ESSELBACH PC, NOLAN M, MACKEY MH, BRINKMANN M Mucle metabolism during 30,60, and 90 s of maximal cycling on an air-braked ergometer. *Eur J Appl Physiol* 63: 354-362 (1991)

YAMAMOTO M, KANEHISA H Dynamics of anaerobic and aerobic energy supplies during sustained high intensity exercise on cycle ergometer *Eur J Appl Physiol* 71: 320-325 (1995)

ZAMPARO P, CRAPELLI C, GUERRINI G Energetics of kayaking at submaximal and maximal speeds. *Eur J Appl Physiol* 80: 542-548 (1999)

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